Motorcycle Helmets Associated with Lower Risk of Cervical Spine Injury: Debunking the Myth

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BACKGROUND: There has been a repeal of the universal helmet law in several states despite definitive evidence that helmets reduce mortality, traumatic brain injury, and hospital expenditures. Opponents of the universal helmet law have successfully claimed that helmets should not be required because of greater torque on the neck, which is thought to increase the likelihood of a cervical spine injury. There is currently insufficient evidence to counter claims that helmets do not increase the risk of cervical spine injury after a motorcycle collision. The objective of this study was to determine the impact of motorcycle helmets on the likelihood of developing a cervical spine injury after a motorcycle collision.

STUDY DESIGN: We reviewed cases in the National Trauma Databank (NTDB) v7.0 involving motorcycle collisions. Multiple logistic regression was used to analyze the independent effect of helmets on cervical spine injury. Cases were adjusted for age, race, sex, insurance status, anatomic (Injury Severity Score) and physiologic injury severity (systolic blood pressure < 90 mmHg), and head injury (Abbreviated Injury Score > 3).

RESULTS: Between 2002 and 2006, 62,840 cases of motorcycle collision were entered into the NTDB; 40,588 had complete data and were included in the adjusted analysis. Helmeted riders had a lower adjusted odds (0.80 [CI 0.72 to 0.90]) and a lower proportion of cervical spine injury (3.5% vs 4.4%, $p < 0.05$) compared with nonhelmeted riders.

CONCLUSIONS: Helmeted motorcyclists are less likely to suffer a cervical spine injury after a motorcycle collision. This finding challenges a long-standing objection to mandatory helmet use that claims helmets are associated with cervical spine injury. Re-enactment of the universal helmet law should be considered in states where it has been repealed. (J Am Coll Surg 2011;xx:xxx. © 2010 by the American College of Surgeons)

There has been a sharp rise in the number of motorcyclists on the road over the last 10 years in the United States and abroad. Motorcycle injuries in the United States have increased by approximately 5,000 per year since 1997 and the incidence of motorcycle fatalities has nearly doubled since that time.[1,2] In developing countries, traffic deaths are projected to be the third most important health problem by 2020, and a large proportion of these deaths involve either motorcycles or motor scooters.[3] In Vietnam, for example, an estimated 60% of all road traffic deaths involved motorcycle riders or their passengers.[4]

Numerous studies have demonstrated that helmets reduce mortality and traumatic brain injury after a motorcycle collision.[5-8] The National Highway Traffic Safety Administration estimates that helmets reduce mortality by 35% and traumatic brain injury by 67%.[9] A recent Cochrane review on the subject confirmed the findings showing the strong evidence of the benefit of motorcycle helmets in reducing mortality and traumatic brain injury.[10]

Even with this preponderance of evidence that proves that helmets reduce traumatic brain injury and mortality,

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many states, including Florida, Pennsylvania, and Texas, have repealed their universal helmet laws due to strong lobbying efforts of some motorcycle riders.[11] Attempts to legislate mandatory helmets laws in developing countries have also met significant resistance.[12-14]

Motorcyclists who lobby against these laws often claim helmets increase the risk of cervical spine injury due to the increased weight of the helmet on the head. A study by Goldstein[15] is often cited, which suggests this may be true. Even through the study had many limitations and no other investigators have replicated the findings, subsequent analyses have not conclusively refuted the Goldstein study by showing that helmets are not associated with an increased likelihood of cervical spine injury.[10]

The objective of this study was to use the largest available trauma database to determine the impact of motorcycle helmets on the likelihood of developing a cervical spine injury after a motorcycle collision.

METHODS

This was a retrospective analysis of all registered cases of motorcycle collision in the National Trauma Data Bank (NTDB) that occurred between 2002 and 2006. The NTDB is managed by the American College of Surgeons and is a convenience sample in that it consists of data voluntarily reported by trauma centers around the United States and its territories. Although all participating institutions are encouraged to submit complete data, some centers do not routinely enter data regarding safety equipment for motorcyclists.[16] A total of 680 of 712 (96%) reporting hospitals included information on motorcyclists and helmet use. This study was restricted to patients from these hospitals that reported use of safety devices.[17] Detailed information on the specific data collection procedures for the NTDB has been published elsewhere.[16]

Cases involving motorcycle collision as a rider or passenger (E-Code 810.x to 825.x, series 0.2 or 0.3) were identified and an electronic search of all International Classification of Diseases (ICD version 9) external cause of injury codes for motorcyclist-related collisions in the NTDB was undertaken. Injury to the cervical spine included ICD-9 codes (952.00–952.09; 952.16; 806.11, 16, 31, 36, and 71) representing bone and nonbone injury, anterior and central cord syndromes, open and closed cord injuries, complete and incomplete spinal cord injury, and spinal cord injuries not otherwise specified (NOS).

Motorcycle riders and any passengers on the motorcycle that were 18 years of age or older were included in the analysis. Demographics and characteristics of the collision, including age, sex, race, crude mortality, injury severity and type, injury intent, and mechanism of injury were compared between helmeted and nonhelmeted motorcyclists. The Student's *t*-test was used to compare continuous variables and chi-square was used to compare categorical variables for bivariate analysis. All analysis was carried out using STATA v10.[18] The Johns Hopkins Institutional Review Board approved this study.

A multiple logistic regression was undertaken to assess the independent effect of motorcycle helmets on the primary dependent variable of injury to the cervical spine. The regression was adjusted with an extensive set of covariates that have been shown to affect trauma outcomes including patient age, severity of injury, severity of head injury, race, sex, and insurance status. To adequately adjust for injury severity, the Injury Severity Score (ISS) was used to measure the magnitude of anatomic injury, and the presence of shock on arrival at the emergency department (systolic blood pressure < 90 mmHg) was used to measure severity of physiologic injury in each patient.[19] Given the importance of severe head injury in this analysis, we also controlled for severe head injury, which was defined as Abbreviated Injury Score (AIS) ≥ 3 in the head region.

Patients were also adjusted for demographics including age (years), sex, and race (black, white, Hispanic, and others). Patient race and ethnicity were included because evidence demonstrates racial disparities in medical treatment and outcomes after trauma.[20] Insurance status (uninsured, commercial insurance, government insurance) was added to control for differences in outcomes based on insurance status.[20] Finally, patient sex was included because there is evidence that women have a survival advantage over men after severe trauma [21,22.] It is also may be that men display greater risk-taking behavior than women, which may potentially confound the association between helmet use and cervical spine injury.

To account for missing data in the NTDB, a sensitivity analysis using multiple imputation was undertaken. The dataset was imputed 5 times using Rubin's Rules.[23] A multiple logistic regression was then performed on the imputed dataset using the same covariates that were included in the original nonimputed (list-wise deletion) dataset. The outcomes of the imputed multiple logistic regression included mortality and cervical spine injury in helmeted versus nonhelmeted motorcyclists.

RESULTS

Between 2002 and 2006, 1,862,348 patient cases were entered into the NTDB; 1.46 million of these cases were entered at hospitals that report motorcycle-related events. Of these, 59,274 were involved in motorcycle collisions. Among the total cases of motorcycle collision, 40,890 (69%) had complete records for analysis (Fig. 1). Approx-

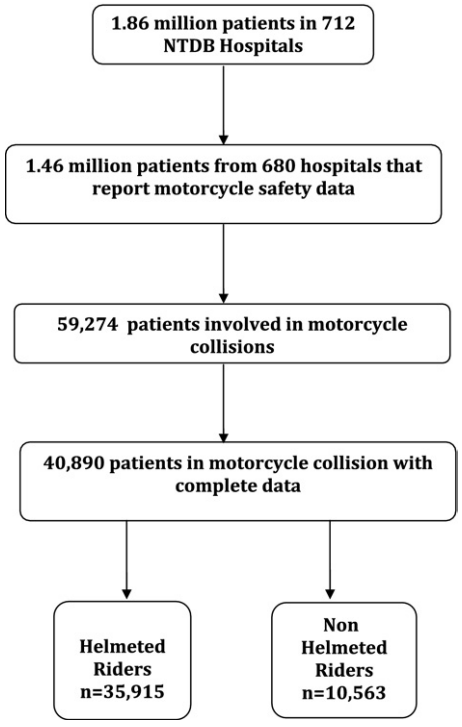

Figure 1. Patient selection in National Trauma Databank (NTDB).

imately 4% (n = 2,620) of riders involved in motorcycle collision died from their injuries. Helmets were worn by 77% of the riders.

Demographic information on helmeted and nonhelmeted riders is presented in Table 1. Helmeted riders had similar age and gender profile compared with nonhelmeted riders. Nonhelmeted motorcyclists were more frequently Caucasian and more likely to be uninsured.

Injury severity characteristics and crude mortality in nonhelmeted riders involved in a motorcycle collision compared with helmeted riders in a motorcycle collision are presented in Table 2. Nonhelmeted riders had a greater proportion of severe head injury (18.9%, $p < 0.001$), shock on admission (5.8%, $p < 0.001$), Injury Severity Score (mean 14.7, $p < 0.001$), and crude mortality (6.2%, $p < 0.001$) compared with their helmeted counterparts.

The unadjusted prevalence of cervical spine injury, mortality, and traumatic brain injury among helmeted compared with nonhelmeted riders is represented in Figure 2. A greater proportion of nonhelmeted riders had traumatic brain injury and died compared with helmeted riders. Unadjusted analyses revealed that cervical spine injury was significantly less likely in helmeted riders compared with nonhelmeted riders (3.5% vs 5.4%, $p = 0.001$).

After controlling for potential confounders in the multiple regression model, helmeted riders had significant, 22% reduced odds of cervical injury (0.78 [95% CI 0.68 to 0.88]) and 65% decreased odds of traumatic brain injury (0.35 [95% CI 0.33 to 0.38]) after a motorcycle crash when compared with nonhelmeted riders (Fig. 3). Helmeted riders also had a 37% decreased odds of death (0.63 [95% CI 0.55 to 0.73]) compared with their nonhelmeted counterparts.

After imputing the dataset for the sensitivity analysis, helmeted riders had a 21% reduced odds of cervical injury (0.79 [95% CI 0.69 to 8.89]) and a decreased odds of mortality (0.64 [95% CI 0.57 to 0.71]) compared with nonhelmeted riders.

Table 1. Patient Demographic and Injury Severity Characteristics of Helmeted Motorcyclists Compared with Nonhelmeted Motorcyclists Involved in Collision

Variable	Helmeted (n = 35,799)	Nonhelmeted (n = 10,563)	p Value
Male, %	87.3	85.9	<0.001
Age, y, mean (SD)	38.9 (13.4)	38.4 (12.6)	<0.001
Insurance, %			<0.001
Commercial	51.3	39	
Government	7.8	6.2	
None	18.5	23.4	
Race/ethnicity, %			<0.001
Black	8.8	7.5	
White	82.1	84.6	
Hispanic	4.2	5.2	
Other	4.9	2.7	
Injury Severity Score (ISS)			
ISS, mean	13.4	14.7	<0.001
ISS < 9	34.3	32.2	<0.001
ISS ≥ 9 < 16	34.4	31.2	
ISS ≥ 16 < 25	16.8	18.3	
ISS ≥ 25	14.5	18.4	
Shock, % (systolic blood pressure ≤90 mmHg)	4.8	5.8	<0.001
Traumatic brain injury (Abbreviated Injury Scale ≥ 3), %	8.5	18.9	<0.001
Crude mortality, %	3.5	6.2	<0.001

DISCUSSION

This analysis of the largest trauma database ever assembled demonstrates that injured motorcycle riders are significantly less likely to suffer from a cervical spine injury when wearing a helmet compared with nonhelmeted riders, effectively debunking the myth that motorcycle helmets are associated with higher risk of cervical spine injury after a crash. There have been several studies that showed that helmets reduce traumatic brain injury and mortality asso-

Table 2. Prevalence of Various Cervical Spine Injuries in Helmeted versus Nonhelmeted Motorcycle Riders

	Helmeted riders (n = 35,799)		Nonhelmeted riders (n = 10,563)		
Variable	**n**	**%**	**n**	**%**	**p Value**
All	1,245	3.48	565	5.35	<0.00
Closed vertebral column fracture	1,076	3.01	510	4.83	<0.00
Open vertebral column fracture	2	0.01	1	0.01	<0.66
Vertebral column fracture with closed spinal cord injury	108	0.30	37	0.35	<0.43
Vertebral column fracture with open spinal cord injury	5	0.01	2	0.02	<0.72
Spinal cord injury without vertebral column fracture	122	0.34	35	0.33	<0.88

ciated with a motorcycle crash, but this is the first large analysis that demonstrates that motorcycle helmets also protect against cervical spine injuries.[5-8,24] Our results are particularly important considering the precipitous rise in motorcycle collisions and fatalities witnessed in the last decade in the United States and abroad.

This study has significant construct validity because it corroborates previous findings that demonstrated that helmets reduce mortality and traumatic brain injury after motorcycle collisions. The finding that helmets reduce mortality by 37% in this study is the same conclusion as that reached by The National Highway Traffic Safety Administration in their analyses. It was also demonstrated in this study that helmets reduce traumatic brain injury by 65%, which is consistent with the findings of the Crash Outcome Data Evaluation System, in which it was concluded that motorcycle helmets are 67% effective in preventing brain injury.[25] Finally, Croce and colleagues,[26] in their analysis of the National Trauma Databank, found a similar reduced prevalence of cervical spine injury among helmeted riders compared with nonhelmeted riders (3.9% vs 5.9%), as demonstrated in this analysis. That these findings are so consistent with previous well-conducted studies lends face validity to this analysis and corroborates earlier studies.

The finding that helmeted riders are 22% less likely to suffer from cervical spine injury than nonhelmeted riders is inconsistent with results from previous literature. In fact, previous research suggests that helmets have no effect or may even increase the risk of developing a cervical spine injury after a motorcycle collision.[15,11,27] Goldstein[15] concluded, from a study of 644 riders, that the weight of the helmet increases the torque on the neck of the rider and results in more cervical spine injuries, especially when exceeding speeds of 13 miles per hour. The strength of Goldstein's analysis is that it used a detailed dataset with more than 1,045 data elements in an attempt to reconstruct the motorcycle crash as completely as possible. However, its methods, which include a causal model based on regression analysis, have been sharply criticized by several authors, including the National Highway Traffic Safety Administration, for flawed statistical reasoning.[28] Even so, the impact of the Goldstein study in the debate on mandatory helmet laws has been remarkable.

Analyses subsequent to the Goldstein study have included reviews of medical records, autopsy reports, analyses of national databases, and prospective studies, which have produced equivocal results suggesting that motorcycle helmets are neither a risk factor nor a protection against spinal

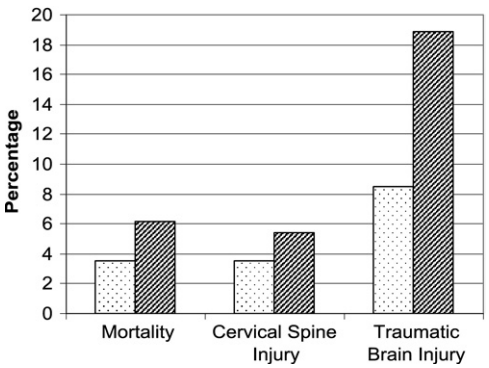

Figure 2. Unadjusted comparison of mortality, cervical spine injury, and traumatic brain injury in helmeted compared with nonhelmeted motorcycle riders (n = 46,362 p < 0.001). Light bar, helmeted; dark bar, nonhelmeted.

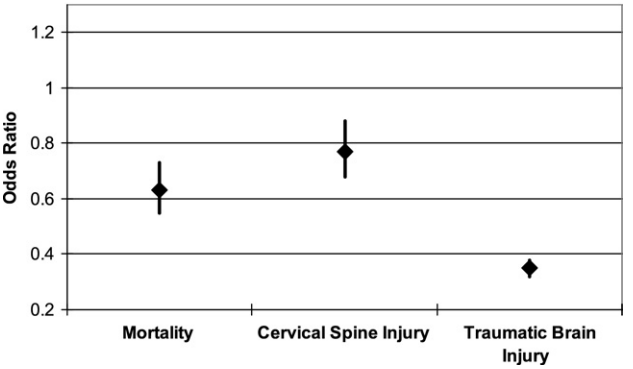

Figure 3. Regression analyses depicting the adjusted odds of mortality (n = 34,919), cervical spine injury (n = 35,264), and traumatic brain injury (n = 35,264) among helmeted versus nonhelmeted motorcycle riders (reference).

injury. According to the Cochrane Review, these studies are generally limited by sample size or appropriate control for confounders. The case control study by O'Connor[27] was the only study to adjust for confounders and found there was no difference in the risk of cervical spine injury between helmeted riders and their nonhelmeted counterparts. Of the 14 studies that did not adjust for confounders, only 1 showed that helmets are protective against spine injury.[29]

Among the fundamental weaknesses of previous studies are also limited sample sizes. The largest study included data from 26,425 crashes and the next largest study included 5,328 patients. The majority of studies, however, report data from less than 1,000 cases.[10,26,30] In our study, a population of 40,890 complete cases (likely more than all other studies combined) of motorcycle collisions were analyzed and adjusted for key confounders known to affect trauma outcomes.

The implication of these findings regarding the lower risk of cervical spine injury with motorcycle helmet use should be considered in the ongoing debate about the value of mandatory helmet laws. Although earlier studies have conclusively demonstrated that helmets reduce mortality, traumatic brain injury, and hospital expenditures, this is the only study of adequate sample size and adjustment for confounders to show that helmets are also associated with a reduced risk of cervical spine injury.

Due to the overwhelming epidemiologic evidence that motorcycle helmets reduce morbidity and mortality, there has been a global movement toward legislating mandatory helmet laws.[31] In 1991, the World Health Organization recognized that nonhelmeted riders represented a public health crisis and launched a global helmet initiative to encourage helmet use worldwide.[31] As of 2003, 29 countries had adopted universal helmet laws.[32] Forty years ago, nearly all states required helmets for motorcyclists of any age in the United States. Today, motorcycle helmets are mandatory for all riders in only 20 states, Puerto Rico, and the District of Columbia. Another 27 states require that minors (defined as age younger than 18 years or 21 years depending on the state) wear helmets.

Although we used a large national sample of injured patients to determine the effect of motorcycle helmets on the likelihood of developing cervical spine injury after a motorcycle collision, there are several limitations to this study. Data is voluntarily reported to the NTDB, resulting in possible selection bias. The NTDB also does not have cause of death data, so a causal relationship between mortality and helmet use cannot be determined. Similarly, persons who were involved in crashes, but who did not sustain injuries severe enough to be admitted to a reporting hospital or who died at the scene, were not included in the analysis. However, given that we are using this subset of data in a comparative study of helmeted versus nonhelmeted injuries, the impact of this potential bias should be minimal. Although we had information on several important covariates, we lacked information on potential residual confounders including location of death (eg, emergency department, operating room, ICU), medical or surgical therapies implemented, involvement of drugs and alcohol, or patient comorbidities. This study was limited by its inability to collect information on important crash-related factors such as the speed, force, severity of the crash, involvement of other vehicles, the type of helmet that was worn, weather, and time of day. Finally, the analysis was performed using a dataset with a significant amount of missing data. A multiple logistic regression using list-wise deletion was performed, as was as a robust sensitivity analysis using multiple imputation, and the results were qualitatively similar.

Despite these limitations, this study builds on research in the literature by addressing two significant weaknesses of earlier research: inadequate adjustment for important confounders such as injury severity and insufficient sample size. Using a large national sample, and after controlling for important covariates, our results indicate that helmets significantly reduce cervical spine injury after a motorcycle collision. These findings have implications for legislative policy, particularly when research is evaluated during policy debates regarding whether to repeal or implement state mandatory helmets laws.

Author Contributions

Study conception and design: Crompton, Bone, Oyetunji, Haider

Acquisition of data: Crompton, Bone, Oyetunji, Bolorunduro, Haider

Analysis and interpretation of data: Crompton, Bone, Oyetunji, Pollack, Bolorunduro, Stevens, Cornwell, Efron, Haut, Haider

Drafting of manuscript: Crompton, Bone, Oyetunji, Pollack, Bolorunduro, Stevens, Cornwell, Efron, Haut, Haider

Critical revision: Crompton, Bone, Oyetunji, Pollack, Bolorunduro, Stevens, Cornwell, Efron, Haut, Haider

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